BACK

Wind patterns in the Georgia Basin – the Salish Sea.

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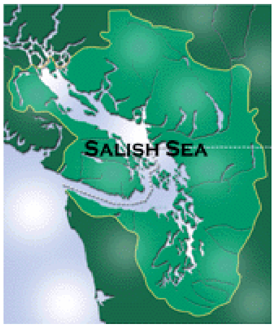
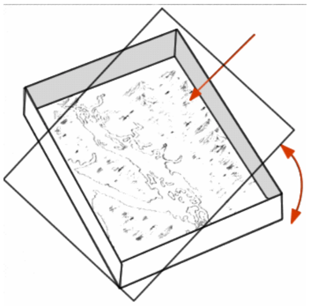


The winds in the Salish Sea are very strongly influenced by the mountains within the region. The winds do not simply flow from any and all directions but are steered into specific directions by the local mountains. While the entire region responds to the overall weather pattern forcings, the winds in each part of the region have their own signature winds that result from these forcings. This paper will outline the wind patterns within the Salish Sea as they were discussed in the Environment Canada publication, *The Wind Came All Ways.*

A method was sought in *The Wind Came All Ways* that could be used to distinguish and classify the various wind patterns. The method that was used was the "pressure-slope" concept, which is basically just a measure of the pressure gradient and is a tool to help visualize the general shape of the pressure pattern in the region. The pressure-slope is calculated from the best-fit plane between five stations: Fanny Island, Pemberton, Abbotsford, Quillayute and Estevan Point.



The pressure-slope can be thought of as a plane that is tilted in such a manner that the plane is high where the pressure is high and low where the pressure is low. This plane can have various degrees of tilt and can be rotated into any direction. Since winds blow from high to low pressure it can be expected that the winds would flow "down" the pressure-slope from where it is high to where it is lower. Winds are described by the direction from which they come, i.e. a northerly wind comes from the north. The pressure-slope is named in a similar fashion after the general direction from which a fluid would come when flowing down the slope.

It was found that the local winds could be grouped, fairly successfully, into seven basic patterns that are based on specific ranges of the pressure-slope. The end values of these ranges are the 'turning points' which mark the approximate pressure-slope direction when significant wind changes occur. The turning points are not static, fixed numbers, but can vary by up to 20° on either side of the value given. Occasionally, the momentum of the winds will delay a shift in direction by three or four hours after the pressure-slope direction has changed.

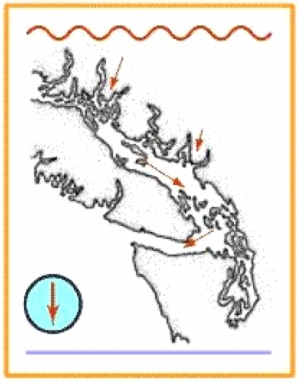
The actual values of the pressure-slope over the last twelve hours are available at Environment Canada's internet site: www.weatheroffice.pyr.ec.gc.ca/marine.

There is a second important aspect of the pressure-slope: its steepness, or gradient. If there is a large difference in pressure between the ridge and the trough, then the pressure-slope is steep. Strong winds result from a steep slope and weak winds from a shallow slope. The value of the pressure-slope steepness ranges from zero, for a perfectly flat slope, to 6 or 8 for a well-developed system. The unit value of pressure-slope steepness that is used is the difference in pressure, measured in millibars (mb), which occurs over a distance of 60 nautical miles (nm). When the steepness is under 0.5 mb per 60 nm, the pressure forcing of the winds is quite weak and local sea and land breeze effects may overwhelm the normal patterns. When winds are caused by pressure differences alone, excluding sea breeze effects, the maximum winds at a well-exposed location may be found to be between six and twelve times the pressure-slope steepness.

The winds that are experienced at the surface are different from those farther aloft, above the boundary layer. This means that the direction of the upper winds, near the top of the boundary layer, is generally veered by about 90° from the pressure-slope direction. Thus, for a northerly pressure-slope, the winds aloft would be from the east. The isobars on a weather map can be used to indicate the direction of the winds at the top of the boundary layer. At this level the winds flow almost parallel to the isobars on a weather map.

Northerly pressure-slope (340° - 030°)

When pressures build over the British Columbia Interior northerly winds spread down through Bute Inlet and out into the Strait of Georgia. The winds move down along the east coast of Vancouver Island as northwesterlies. The winds along the mainland coast remain light and are often from the east. When the pressure-slope steepness is above 1.0 mb per 60 nm, the winds in Bute Inlet are strong and the resultant winds near Vancouver Island may rise to 15 to 20 knots. During the day, after the winds have spread all the way down to near Vancouver, the winds will gradually strengthen if sunny skies allow the development of a sea breeze.



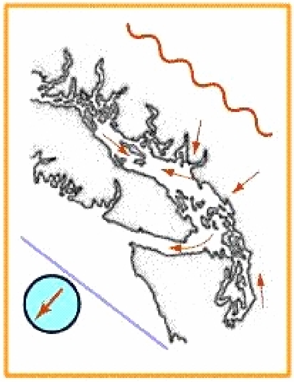
NORTHERLY

With a well developed system, the northwest winds off Vancouver (and sometimes as far back as Nanaimo) may rise to 20 to 25 knots. In the afternoon the winds over the northern sections of the Strait of Georgia weaken and spread over the mainland coast. The winds in the Gulf Islands are about 5 to 15 knots. South of the San Juan Islands the light winds split, to move south through Puget Sound, or west out Juan de Fuca Strait. Local funnelling in Puget Sound can increase the winds to near 20 knots. The winds will be gusty, especially in the winter and spring, for the air is unstable in the low levels, due to the air being cooler than the water. This pattern may last for days.

If the pressure-slope rotates clockwise toward the end of its range (i.e. toward about 030°) the outflow shifts from a Bute Outflow to more of a Fraser River outflow. When this shift occurs the winds in the Strait of Georgia ease, and northeast winds coming out the Fraser Valley strengthen and spread out over the Gulf and San Juan Islands and into Juan de Fuca Strait.

Northeasterly pressure-slope (030° - 080°)

This is another outflow wind pattern caused by high pressure over the BC interior. The strongest outflow wind shifts from Bute Inlet in the north, to Harrison Lake and the Fraser Canyon in the south. Easterly winds begin to spread up the Strait of Georgia near the pressure-slope turning point of 030°. A line of converging winds forms between the northwest winds moving down from Bute Inlet and the southeast winds moving out from the Fraser Valley. This line moves up and down the strait according to very subtle changes in the relative wind strength of the two wind sources, and the temperature of the two air streams.



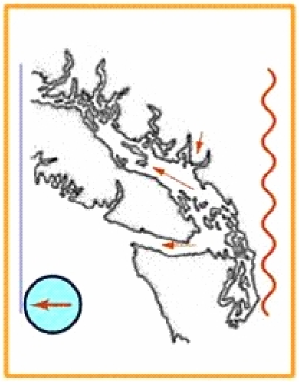
NORTHEASTERLY

When the pressure-slope gradient is weak then the winds across the Strait of Georgia are light and may be quite variable in direction. Northeast winds from the Fraser Valley cross over the Gulf and San Juan islands, then move across Juan de Fuca Strait to pile up along the Olympic Mountains. This flow is channelled westward and can reach speeds of 35 to 40 knots at Tatoosh Island with a strong outflow event. The northerly winds moving into Puget Sound ease as the ridge rotates toward the east and may reverse at times to light southerlies.

A similar pattern of winds can also develop when a front approaches the region from the southwest. The winds are not usually as strong as in the typical outflow event, nor are they as long lasting. An outflow event can last for days and even weeks. When this pattern is associated with an approaching front (without the strong ridge over the Interior) it may only last for hours. Strong southeast winds, associated with the approaching front, may not spread into the Strait of Georgia until the pressure-slope direction rotates closer to easterly.

Easterly pressure-slope (080° - 130°)

The easterly pressure-slope is the most common pattern of winter. During the passage of most winter fronts the pressure-slope directions will range from Northeasterly to Southeasterly depending on the orientation of the approaching front. Once the pressure-slope becomes Easterly, southeast winds spread all the way up the Strait of Georgia. They will strengthen and can reach gale or even storm force with the approach of a strong front. The winds in Howe Sound ease as the pressure-slope direction moves toward 080°.



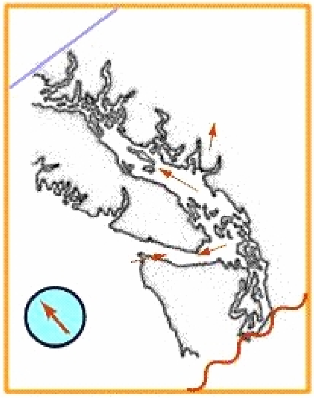
EASTERLY

The winds over the Gulf and San Juan islands try to veer from northeast to southeast, but sometimes they oscillate back and forth around due east. The plume of strong northeast winds which passed across southern Victoria with the Northeasterly pressure-slope now veers more toward the east and becomes more evenly spread across the strait, but it usually weakens as well. Northeasterly outflow winds will continue through the inlets of Desolation Sound but strong southeast winds will spread across the western sections closer to Vancouver Island. Puget Sound winds will shift from northerly to southerly. Occasionally a convergence line between the northerlies and southerlies will form and move northward from Puget Sound across the San Juan Islands.

A lee low may form downwind of the Olympic Mountains, over the water to the northwest of Port Townsend. Race Rocks seems to be near the pivot point of changes. With the pressure-slope direction near 080°, the winds at Race Rocks will be northeast, near 15 knots (with a slope steepness near 3.0 mb per 60 nm), while the winds at Trial and Discovery islands will be much stronger southeasterlies. The winds at Race Rocks will shift to the southeast and strengthen when the pressure-slope direction rotates toward 130°.

Southeasterly pressure-slope (130° - 170°)

As a front moves across the region the pressure-slope rotates clockwise beyond 130°. Strong southeast winds ahead of the front may reach gale force or even storm force 50 knots with the strongest winter storms. The strong plume of winds which began closer to Victoria with an Easterly pressure-slope now moves eastward across the San Juan Islands and over toward the mainland coast. Just ahead of the approaching front the plume of strong southeast winds extends north into Howe Sound where it causes a sharp wind shift from north to south. Behind the front strong southwest winds pour across the northwest corner of the Olympic Peninsula and into Juan de Fuca Strait.



SOUTHEASTERLY

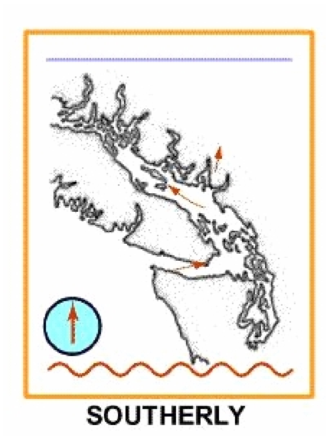
The winds in the Strait of Georgia often ease near or just before the passage of the front, which usually takes place as the pressure-slope direction approaches southerly. The winds in Puget Sound turn from southeast to south to southwest. They strengthen for a time just behind the front then later ease as the pressure equalizes.

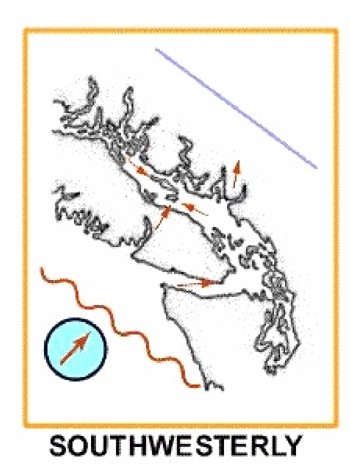
The same pattern, but with much less intensity, can occur when a ridge of high pressure passes to the southeast of the region. Wind speeds up to 20 or 25 knots are common in the northern Strait of Georgia, where local channelling effects are strong. In the south the winds are often only 10 to 15 knots. The winds are generally light northerlies through the inlets and may shift diurnally to a light southerly in the afternoon. The winds in Juan de Fuca Strait are light easterlies. These winds could be called 'pushed' southeasterlies.

BACK

Southerly pressure-slope (170° - 210°) and
Southwesterly pressure-slope (210° - 240°)

Within these two pressure-slope patterns, which are the dominant patterns of summer, the winds oscillate back and forth in the Georgia Basin, as if it is a closed unit, almost like a bathtub. When the pressure-slope is near 170° the westerly winds in Juan de Fuca Strait turn and move up the Strait of Georgia as southeasterlies. Typically, they do not go all the way up the Strait, but converge with light northwest winds that occur over the northern parts of the Strait, somewhere near Qualicum Beach.





When the pressure-slope rotates clockwise toward 240° the northwest winds spread southward through the Strait of Georgia and into the northern parts of the Gulf and San Juan Islands, where they meet the winds coming up from Juan de Fuca Strait. The winds through these islands are normally quite light as they have been released from the confines of their upstream channels, and hence the convergence does not strongly affect the local weather. This oscillation of winds that is seen through the rotation of pressure-slope directions is repeated daily during the sunny days of summer, though, is not always reflected in the pressure-slope values themselves.

Westerly sea breeze winds arise in Queen Charlotte Strait during the afternoon and increase in strength as they funnel through Johnstone Strait in the late afternoon and early evening. These winds enter the northern Strait of Georgia in mid evening and move south along Vancouver Island overnight. The winds on the mainland coast remain light easterlies. During the overnight hours the westerly winds in Juan de Fuca Strait decrease and the winds in the coastal inlets may switch to northerly outflow. Then, as the land heats during the day, the northwest winds in the Strait of Georgia ease (and move onto the mainland coast side), the winds in the coastal inlets shift from a northerly outflow to a southerly inflow and the westerly winds in Juan de Fuca Strait increase. The winds in Juan de Fuca and the coastal inlets reach their strongest values in the late afternoon or early evening. If the pressure-slope backs to, or just east, of 180° the winds in Juan de Fuca Strait move up into the Strait of Georgia where they meet the northwest winds moving down the Strait.

Another line of convergence can also develop within the region. When the pressure-slope is Southerly the winds in Puget Sound are from the south but when the pressure-slope rotates toward the southwest (toward 240°) the westerly winds in Juan de Fuca

Strait turn south into Puget Sound, where they can converge with winds that have passed through the Chehalis Gap south of the Olympic Mountains and turned north into Puget Sound. This is called the ‘Puget Sound convergence zone’. When the westerly winds that approach the Olympic Mountains are strong the converging winds may also be strong, sometimes with dramatic results.

There is one more wind that occurs within this range of pressure-slopes and that is southwesterlies. This could be said to be the key, or signature wind, of these pressure-slopes. Southwest winds occur in two different weather patterns. The most well known southwest wind is called the “Qualicum” for it pours out through Port Alberni Inlet and over the community of Qualicum, then into the Strait of Georgia. A true Qualicum wind occurs when a ridge of high pressure develops along the west side of Vancouver Island. Typically this occurs just ahead of a front that is approaching northern Vancouver Island. Southwest winds may also occur with pressure rises behind the front, but in this situation the southwest winds are not limited to the valley near Qualicum, but can occur over much of southern Strait of Georgia. The strength of a true Qualicum is typically near 25 knots while the southwest winds that occur behind a front will vary with the strength of the rising pressure behind the front. The strongest southwest winds occur with the strong pressure rises that can occur just behind a low that passes directly over southern Vancouver Island.

North of Comox the winds generally remain as light southeast winds until they shift into the northwest as a ridge builds west of the coast. The southwest winds do not always spread right across the Strait of Georgia, but may remain as a light southeasterly along the Sunshine Coast. Temperature plays a dominant role in the changing of the winds during the summer months.

When a front from the west or northwest crosses the region, a ridge builds over the outer coast and causes the pressure-slope direction to shift into the southwest. Fronts approaching from the northwest typically become quite weak after crossing over Vancouver Island, so the associated surface winds are also weak. If, however, the front remains strong after its passage over Vancouver Island, strong westerly winds will develop in Juan de Fuca Strait along with strong northwest winds in the Strait of Georgia.

Westerly pressure-slope (240° - 340°)

WESTERLY

The westerly pressure-slope pattern occurs when the ridge of high pressure lies just west of Vancouver Island on a north to south, or slightly northeast to southwest line. This pattern does not occur as frequently as the southwesterly pattern. This pattern is similar to the southwesterly pressure-slope pattern except that northwest winds have spread all the way down the Strait of Georgia and will reach Vancouver, when the pressure slope rotates west of 240°.

In the summer, the strongest winds are the northwesterlies in the Strait of Georgia, for they are strengthened by drainage winds from the inlets. The westerlies in Juan de Fuca Strait are weaker but will tend to be strongest on the Washington State side. Howe Sound has light to moderate northerly winds. Diurnal variations still occur.

Throughout the year westerly winds also develop with the rising pressure that occurs after the passage of a front. The strongest westerly winds in both the Strait of Georgia and Juan de Fuca Strait, occur with a frontal passage as the pressure-slope turns to Westerly. These winds can be dramatic, for they can rise from light, to gale or even storm force, in a matter of minutes. They tend to ease within a couple hours once the pressure across the region is equalized.

As the pressure-slope turns more toward the west the convergence line in Puget Sound moves farther south until eventually all the winds through the Sound are northerlies. The wind speeds tend not to be strong.

Concluding summary

The winds in Puget Sound and Georgia Basin are complex due to the many significant mountain peaks, ranges and valleys, but they are not without order. The complexity is seen when the winds for any one location change over time, seemingly without reason. The order can be recognized, however, when the local winds are seen as part of a whole, which responds in definite ways to outside pressure patterns that affect the entire region. The pressure-slope is a simple concept that can be used to categorize the various patterns of pressure over the region and their corresponding patterns of winds.